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SOIL SURVEY NOTES

BY

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NORTH LAKHIMPUR.

Soils of the Plains.

The North Lakhimpur District is a continuation eastward of the Bishnath District.

The tea gardens are concentrated in the north under the foothills, since the land nearer the Brahmaputra is very low lying and much of it below flood level. For similar reasons there is only one garden east of the Subansiri; this is on a low *bam*, or bank, other than which the land again is very little above normal rains water level.

The foothills running North-east to South-west drop to the plain abruptly, in general, and join the plain at about 500 feet above sea level.

The 350′ contour is about 2 to 4 miles distant measured along the general direction of fall, *i. e.*, South-east.

Below this line there is a marked decrease in slope, the fall being only about 50 feet in 6 to 10 miles. Except on gardens on, or close under, the foothills therefore there is not very much fall for drainage. It is a district of notably continuous rainfall in the rainy season, added to which there is always considerable water in the subsoil from seepage from the near hills.

Wetness of the soil must be the feature of the plains gardens.

The land generally, however, is such as can stand such conditions excellently, being a stretch of sand gently undulating so that there is a natural run off from the surface.

The best tea soils of the plains are on the low banks formed by such undulations. Poorer tea is found in the hollow places between them.

Not only do the higher lying soils enjoy an advantage in situation, but they are almost invariably distinctly different soils.

While the low banks are coarse sands somewhat reddish in colour, the land between them is occupied by more silty soil much lighter in colour.

Samples taken from adjoining places show the difference between the two classes of soil.

	Good reddish soils from low banks.				Poorer silty soils from lower spots.			
	1 Harmutty	2 Silonibari.	3 Dejoo.	4 Doolahat.	5 Harmutty.	6 Silonibari.	7 Dejoo.	8 Doolahat.
Soil Type ...	21 345	21 345	21 435	21 345	23 451	23 415	24 315	23 451
Coarse sand ...	17	32	25	32	4	7	15	6
Fine sand ...	44	40	38	34	50	49	34	39
Silt ...	17	13	9	14	19	19	17	23
Fine silt ...	15	9	15	12	17	16	18	21
Clay ...	4	2	7	3	7	5	10	7
Loss on ignition ...	3·7	3·2	5·1	4·1	3·5	4·2	5·0	4·7
Grandeau organic matter...	1·14	1·12	1·8	2·55	1·21	1·34	1·8	2·0
Nitrogen ...	·102	·116	·113	·150	·091	·120	·106	·140
Acidity (Hopkins) ...	151	42	537	50	290	127	566	156

It will be observed that the better soils are no better off than the poorer ones in nitrogen or organic matter, and that the acidity varies fairly widely in each class ; nor can any explanation of the difference be traced to mineral constituents. The only significant difference lies in the amount of coarse sand present.

Of the good soils, the Harmutty sample is hardly representative ; the more westerly soils around Harmutty are not so coarsely sandy as the average North Lakhimpur soil.

Of the poorer soils, the sample from Dejoo again is hardly representative. It represents a heavier soil of that garden from a spot lower than that carrying the best tea, but is distinctly a better soil than the average poor whitish soil of the district.

It holds as a rough rule for the greater part of the district that the good soils have over 20 % coarse sand, and the poor soils less than 10 % coarse sand.

In the soils of the Jorhat District, across the Brahmaputra, a similar relationship of coarse sand with fertility is often noticeable on the flatter land; but in the Jorhat district less coarse sand is necessary.

The coarsely sandy soils drain rapidly and remain naturally well aerated in spite of the wetness of the district. The difference in colour is probably also an effect of aeration, the better aerated soils becoming reddish. Low lying, insufficiently-drained stretches of coarse sand are, generally, also light in colour.

It should be noticed that the poorer soils of this district are of the silt-loam class (generally 2. 3. 4 type) which in most districts does very well under tea.

The failure of this class of soil here can be ascribed only to the exceedingly wet climate. Where drainage is possible such soils would undoubtedly benefit from really efficient drainage.

On many sandy-soil gardens of North Lakhimpur there is little to be seen of artificial drainage.

The coarsely sandy banks do very well without, and in view of the suffering of drainside bushes during dry weather on such coarsely sandy soils, and of the great practical difficulty of keeping drains at all, these coarse soils generally may be well left without artificial drainage.

The lower lying and more silty soils, however, most certainly cannot be expected to improve unless first efficiently drained. These closer-grained soils are also sandy and contain little clay, and drainage therefore still offers practical difficulties which must often be met by the use of wide drains; though, if they will hold up, narrow drains are to be preferred.

There is fortunately no need for drains to be close in the majority of cases. Where, as is often the case, the siltier soil is a deposit in the troughs on undulating land, the drains should run in

the bottoms of the troughs wherever necessary. Where there are broader expanses probably 60 feet apart is as close as drains need be.

The chief objection to more drains than are absolutely necessary, (in addition to the expense of making and keeping them) is the suffering during the dry season of the bushes immediately alongside the drains.

An example (probably an extreme case) illustrates the possible loss from this cause.

At Tocklai there are plots where each line of bushes is separately plucked and weighed up.

Lines of unpruned tea during the very dry season 1919 gave less than 5 mds. tea per acre. These were immediately alongside drains. Tea of the same age and treatment, not immediately alongside drains, gave over 10 mds. per acre.

Here is a case, then, where the loss caused to drainside bushes amounted to more than half the crop.

This tea is planted $5' \times 5'$ square.

Now suppose the drains had been made 20 feet apart. Then 2 bushes out of every 4, or half the bushes on the area, would be drainside bushes giving less than half crop. That area would be losing over 25% of its crop; tea that should be giving 10 mds. would yield less than $7\frac{1}{2}$ mds.

On similar soil at Tocklai there is an area with drains 70 feet apart, and the bushes in the middle show no sign of suffering from under-drainage. On this area only 2 bushes out of 14 can suffer from drainside effect, and the loss from this cause over the whole area would be 7% only: we lose $\frac{2}{3}$ md. out of ten, instead of $2\frac{1}{2}$ mds.

Closer drains may be necessary even on coarse sands in less favourably situated places; but it is important not to make drains closer than is necessary. They may, however be as deep as practicable with advantage.

Drainside suffering is enormously reduced by shade. It is less from a narrow drain, than from a wide drain. A line of shade

trees or a hedge of Boga Medeloa along the south side will make drainside suffering, from over dry soil, almost negligible.

There will still, however, remain some loss of efficiency of drainside bushes, by loss of soil from one side, and from enforced neglect of cultivation near the drain edge. This lack of cultivation is particularly necessary on sands, or the drain falls in, and possibly the drainside bushes also.

On a large number of places in North Lakhimpur, beautiful high yielding tea is seen on the sandy low banks without any artificial drainage at all; and for the above reasons great caution is recommended before attempting expensive schemes of drainage in such situations.

At the same time, there are places where drainage has been beneficial, or is still necessary. These places are chiefly on the closer grained soils of the hollows, but there are also cases of coarse sands which benefit: for example, wide stretches of flat land with little undulation, particularly if close to higher land from which water seeps.

The typical good sandy soil of North Lakhimpur may be taken as of the 2, 1, 3, or 2, 1, 4 type. Coarser soils, where coarse sand exceeds the fine sand are also found, *i.e.*, the 1, 2, 3 and 1, 2, 4 types. Where the coarse sand is not altogether excessive these types very closely resemble the 2, 1, 3 and 2, 1, 4 types and do equally well, but where the amount of coarse sand is excessive, and clay also is exceptionally low, such soils will show signs of suffering after a dry cold weather, and the tea become liable to stem diseases.

The siltier types like the 2, 3, 4 and 2, 4, 3, as already explained, do not as a rule do so well in this district as the more sandy soils.

On the plains gardens, the following soil types occur :—

Harmutty—average good soil ... 2, 1, 3, 4, 5.
—also occurs ... 2, 3, 4, 5, 1.

Tonijan—average good soil ... 2, 1, 4, 3, 5.

Doolahat—average good soil ... 2, 1, 3, 4, 5.
—also occurs ... 2, 3, 4, 5, 1.

Silonibari—average good soil ... 2, 1, 3, 4, 5. (6 examples).
2, 1, 4, 3, 5.

soils more sandy ... 1, 2, 3, 4, 5. (4 examples).
1, 2, 4, 3, 5. (2 examples).

also occurs ... 2, 3, 4, 1, 5. ,,

The large number of analyses from this garden, includes practically all the types of soil from the plains of North Lakhimpur. If any other garden of the low ground of the district were as completely sampled the same types of soil would probably be found. Except for the local variation indicated the whole district is a sweep of much the same soil.

Bogabheel ... ... 2, 3, 1, 4, 5.
2, 3, 4, 1, 5.

Dejoo—average good soil ... 2, 1, 4, 3, 5. (2 examples).
also occur ... 2, 3, 4, 1, 5.
and ... ... 2, 1, 4, 5, 3.

This last sample is from a small plateau of red heavier soil similar to that of the Tezpur Red bank, and is clearly of older formation than the sands surrounding it.

Koilamari (Joyhing Dn.) average soil 2, 1, 4, 3, 5.
Pathalipam—average soil ... 2, 1, 4, 3, 5. (2 examples).
Derpai—average soil ... 2, 1, 3, 4, 5. ,,
Bordeobam—average soil ... 2, 1, 4, 3, 5.

In all these gardens it will be seen that the 2, 1, 3, and 2, 1, 4, types predominate, as they do in Bishnath ; and on the gardens from which no samples have been obtained, it is clear from inspection that the soils are very similar. As regards soil this district is one with Bishnath, and the greater part of the soil probably originated in the same way, *i.e.*, from the Brahmaputra itself which once appears to have run very close to the hills.

Later deposits from tributaries of the Brahmaputra would however be of similar character.

Similar very sandy soils occur under the Himalayas in the Mal District of the Dooars but these are very rich and are presumed to be largely produced by washing down of good surface soil from the hills. The marked richness of the Mal sands is not common in North Lakhimpur, though there are a few cases of very rich sands, particularly near the hills.

The hills to the north of the Mal district, other than red bank, are of hard rock (softened by weathering at the surface) covered with a shallow layer of very rich soil.

The low hills about the mouth of the Subansiri gorge, for example, are not of rock but of brown earth which appears itself to have been comparatively recently deposited and afterwards cut through by the river.

The following are further examples of the characteristic soils of the district :—

Representative Sandy Soils of Plains of North Lakhimpur

	9 Virgin soil (from Tonijan).	10 Rich coarse sand resembling Mal sands of Dooars (from Koilamari).	11 A soil of normal physical composition, but below average fertility.	12 A fair but too coarsely sandy soil.	13 A thoroughly bad section although of good physical composition.
Soil Type ...	2, 1, 4, 3, 5	2, 1, 4, 3, 5	2, 1, 4, 3, 5	1, 2, 3, 4, 5	2, 1, 3, 4, 5
MECHANICAL ANALYSIS.					
1. Coarse sand ...	26·2	29·5	29·5	64 7	23.6
2. Fine sand ...	42·2	47·4	46·1	23·3	55·1
3. Silt ...	8·5	7·1	6·7	5·8	9·0
4. Fine silt ...	13·7	10·3	11·1	2·9	6·8
5. Clay ...	3·1	1·9	3·5	0.5	2·2
Loss on Ignition ...	5·9	3·7	2·9	2·8	2·7
CHEMICAL ANALYSIS.					
"Grandeau" organic matter (soluble humus) ...	2·90	1·90	1·20	1·20	0·66
Acidity (Hopkins) ...	73	858	96	...	1018
Total Nitrogen ...	·170	·105	·060	·078	·044

With the exception of those of Bogrie and Silonibari very few analyses of North Lakhimpur soils showing physical composition existed.

This note is based mainly on samples collected by the writer while touring recently, and for the analyses he wishes to thank Mr. L. N. Phukan of this laboratory.

Time did not allow of determinations of mineral constituents. Older analyses show fairly wide variation in this respect, but deficiencies in potash or phosphoric acid or both are common, and should be made up by manuring.

As in Bishnath, maintenance of fertility in North Lakhimpur depends most directly on keeping up the content of organic matter, while the great majority of soils will show good results from additions of nitrogen preferably in organic form, as oilcake, fish manure, animal meals and cattle manure.

Soils like No. 9, however, will of course do very well for some time without manuring.

No. 10 also, is an excellent soil though without the abnormal richness of No. 9, and it is also rather too sandy. Lime would be likely to prove useful on this soil.

No. 11 is physically an excellent soil but higher organic matter would be of great advantage, while continuous additions of nitrogenous manure would yield very profitable results at present prices.

No. 12 does well enough in normal seasons. Its liability to suffering from the effects of drought and consequent diseases could be partially overcome by an increase of well-rotted humus (*e. g.*, by green manuring in the wet season) and by the use of potash manures.

The district contains very few throughly bad soils like No. 13. This soil could be worked up by manuring, but it carries very poor hybrid tea, and when good land is available, such a soil is not worth the replanting which would be necessary as a start. Note its very low contents of "Grandeau" organic matter, and of nitrogen.

These very sandy types of soil are particularly liable to the root disease known as Brown Stump Rot (*Hymenochaete noxia*), and the loss from this disease in North Lakhimpur may be fairly described as enormous.

It is true that good healthy bushes appear more resistant than bushes growing poorly; but the disease is present on rich soils and on poor, on highly acid soils and on soils nearly neutral. So important is the suppression of this disease to the district that a note by the Mycologist on its treatment is given in this number, although the disease has frequently been referred to in previous numbers.

Red Bank Soils

As in the Dooars, Mangaldai and Bishnath the old alluvium (Red Bank soil) occurs on the low hills at the base of the Himalayas in North Lakhimpur.

At *Bogrie* above Harmutty is an undulating plateau of red bank soil, which ends with an abrupt drop to the plains.

The following closely related types of soil occur :—

1, 2, 3, 5, 4
2, 1, 3, 5, 4
2, 3, 1, 5, 4
3, 2, 1, 5, 4
3, 2, 5, 1, 4

Where each type is derived from the one written above it by a relative increase in one constituent only.

The less closely related types 1, 3, 5, 2, 4 and 2, 5, 3, 1, 4 also occur.

The character of the land and appearance of the soil and bushes at Bogrie are strongly reminiscent of the best of the lighter-soiled red bank gardens of the Dooars. Yet of the 7 soil-types found at Bogrie none are common in the Dooars.

The 1, 2, 3 type occurs at Matelli and Moortee.
The 2, 1, 3 type occurs at Moortee.
The 1, 3, 5 type occurs at Matelli and Looksan.
The other four types have not been found in the Dooars.

These Bogrie soils are very distinctly true red bank soils. The clay averages 17% and is in some cases over 20%. Clay always exceeds fine silt, and this is a common characteristic of red bank soil.

What is uncommon is the occurrence of both fine sand and silt in large quantity. These Bogrie red soils have apparently suffered weathering to a less extent than those of the Dooars, and are physically more closely related to the red bank soils of Tezpur.

Chemically they resemble the best red bank soils of the Dooars, being highly acid and very rich in organic matter and nitrogen.

Loss on ignition average about	9½%.
"Grandeau" organic matter (soluble humus)	3.0%.
Nitrogen about	0.15%.

Acidity is also high for the type of soil.

In these respects they present a marked contrast to the Red Bank soils of Tezpur and Bishnath.

Except on a few small patches where clay is high and organic matter deficient, these red bank soils grow remarkably fine tea. It is interesting to note that these soils while in their present splendid physical condition do so well without artificial drainage, as the Dooars Red Bank soils used to do.

At *Joyhing* another bank of red soil slopes down to the plains.

This garden has not been so completely sampled, but samples selected as representing a very light and two heavier soils were of the following types :—

1, 2, 3, 4, 5.
2, 1, 5, 4, 3.
3, 2, 5, 1, 4.

The 1, 2, 3, 4, 5 type occurs at Matelli and Moortee and is related to the 1, 2, 3, 5, 4 type at Bogrie. The specimen at Joyhing, however, is probably not a true red bank soil formed *in*

situ but represents a coarse sand separated from finer particles by washing from higher slopes.

The 2, 1, 5 is related to the 2, 1, 3 type found at Bogrie and is fairly common in Tezpur, while the 3, 2, 5, 1, 4 type occurs at Bogrie. We have not enough data for close comparison, but it is probable that the Joyhing soils are of much the same types as at Bogrie and were originally very generally similar, but having been longer under cultivation would probably give lower average figures for organic matter and nitrogen.

Like most red bank soils, however, these Joyhing soils last very well, and excellent tea is to be seen there.

On the plains only a few small blocks of red bank soil remain above the plain. One is the small plateau referred to at Dejoo, where it now forms the polo ground; but some of the tea land at Dejoo is also more brightly red and contains more clay than the average North Lakhimpur new alluvium and may be mixed with red bank soil which here appears near the surface.

The polo ground sample is of the 2, 1, 4, 5, 3 type, a type not found in the Dooars, but occurring at Bogrie and resembling the lighter red bank soils of Bishnath and the very similar type 2, 1, 3, 5, 4 which is one of the commonest types of soil on the Tezpur red bank.

Red soils occur on the plains in other places, for example, near Pathalipam along the road through the jungle from Lakhimpur and may be seen to be of considerable depth where the road is cut by streams. These soils, however, are very little, if any, higher than the surrounding normal sand of the plains, and appear from casual inspection to contain little more clay. It is probable that these patches represent wash from more northerly red bank hills.

The dry beds of rivers and streams often contain very bright red deposits, both along the road referred to, and in other parts of the district. The colour of the water often gives names like Ranga Naddi (red river), Ranga Jan (red stream). Such colour, however, is not necessarily due to red soil carried in suspension; for streams both here and in other parts of Assam may often be

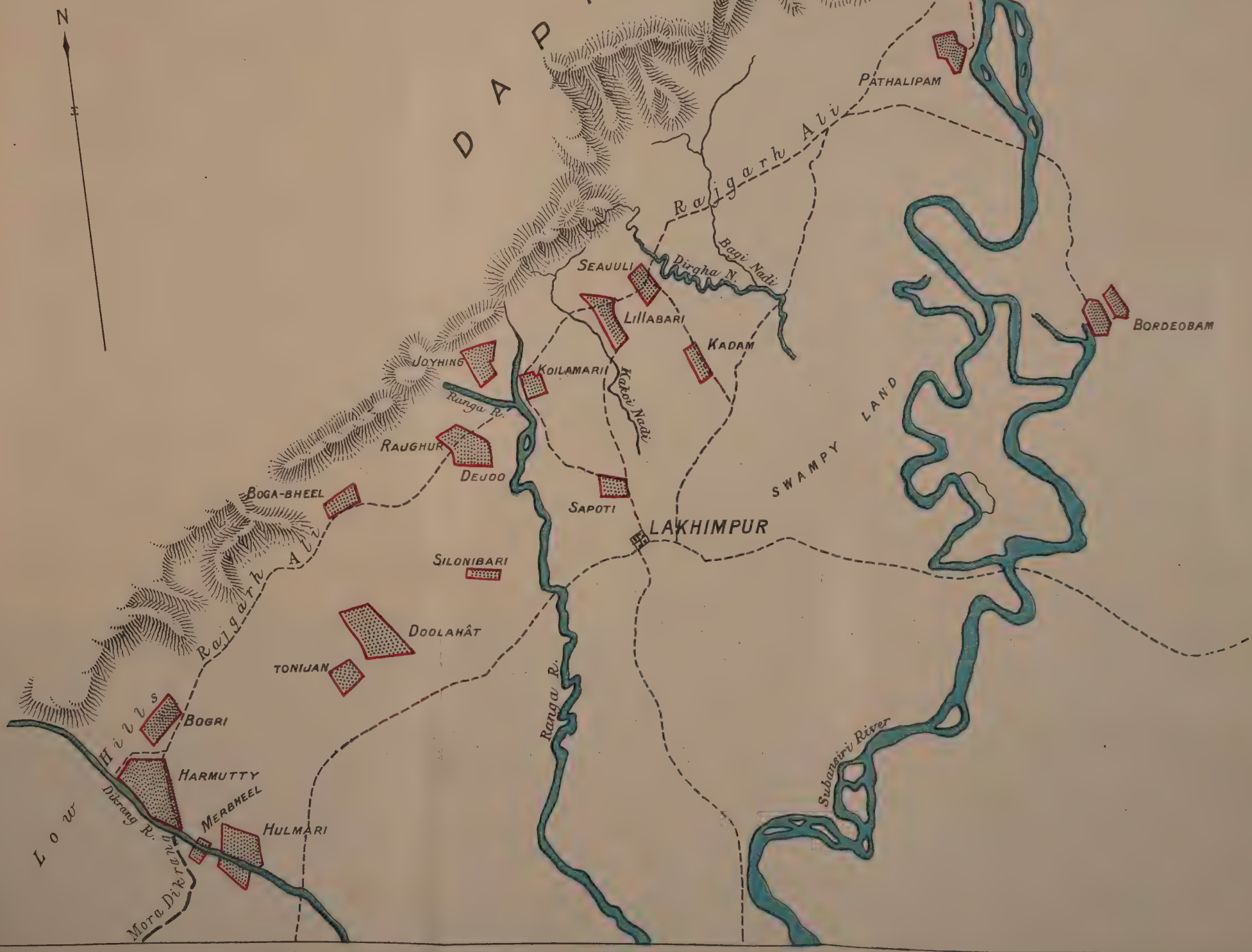
observed to be bright blood-red in colour, when stagnant with no soil in suspension, and the colour may then be clearly observed to be due to the operations of "iron bacteria."

Examples of North Lakhimpur Red Bank Soils.

	Splendid tea.	Poorer tea.
MECHANICAL ANALYSIS.		
Soluble in dilute acid	0·6	0·1
Coarse sand	16·1	17·7
Fine sand	19·0	25 9
Silt	25·3	20·2
Fine Silt	8·5	8·4
Clay	18·3	20·3
Loss on ignition	12·0	7·4
CHEMICAL ANALYSIS.		
"Grandeau" organic matter (soluble humus) ...	3·70	1·53
Insoluble silicious matter	76·9	81·3
Acidity (Veitch Albert)	2524	1621
Total nitrogen	0·150	0·119
„ phosphoric acid	0·089	0·070
Available phosphoric acid	0 012	0·008
„ potash	0·008	0·012
„ lime	0·054	0·058
„ magnesia	0·056	0·039

SKETCH MAP
OF
TEA DISTRICT
OF
NORTH LAKHIMPUR

1" = 4 Miles



IMPERIAL ART COTTAGE, CALCUTTA.

DIAGRAM 2

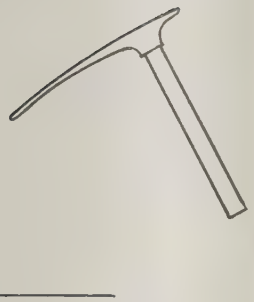


FIG. 3.

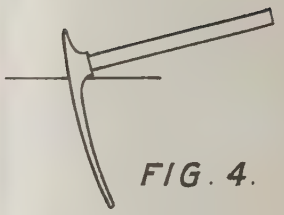


FIG. 4.

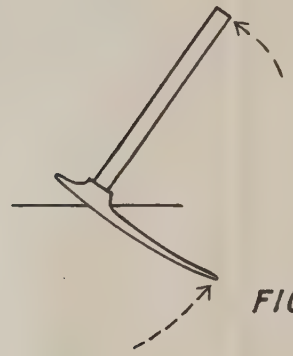


FIG. 5

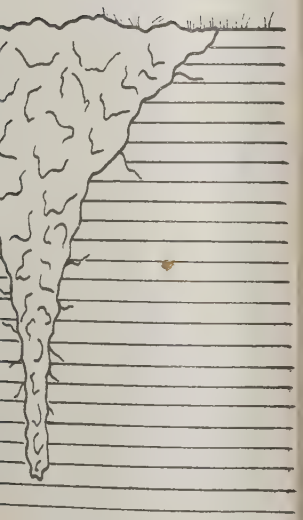


FIG. 6.

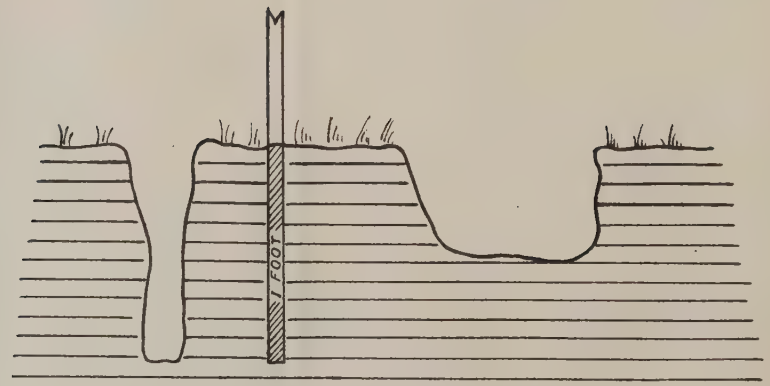


FIG. 7.

DIAGRAM 2

FIG. 3.

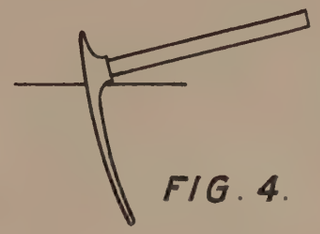


FIG. 4.

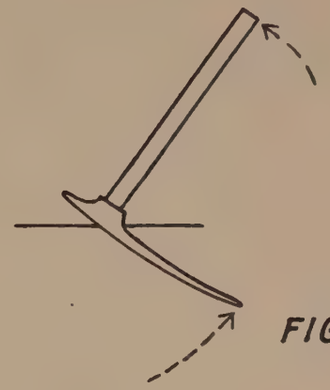


FIG. 5

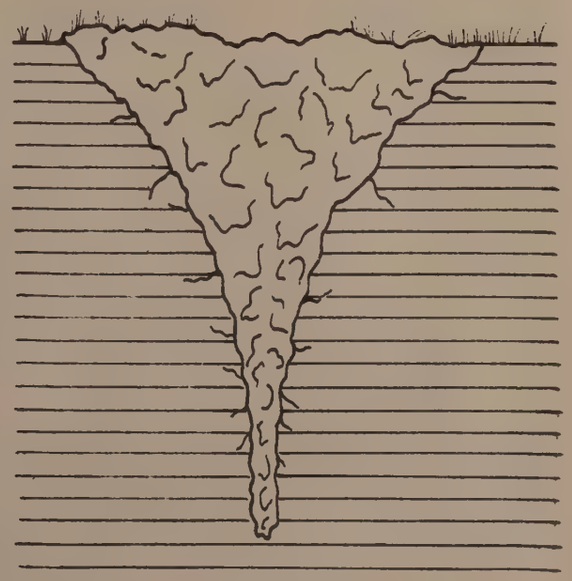


FIG. 6.

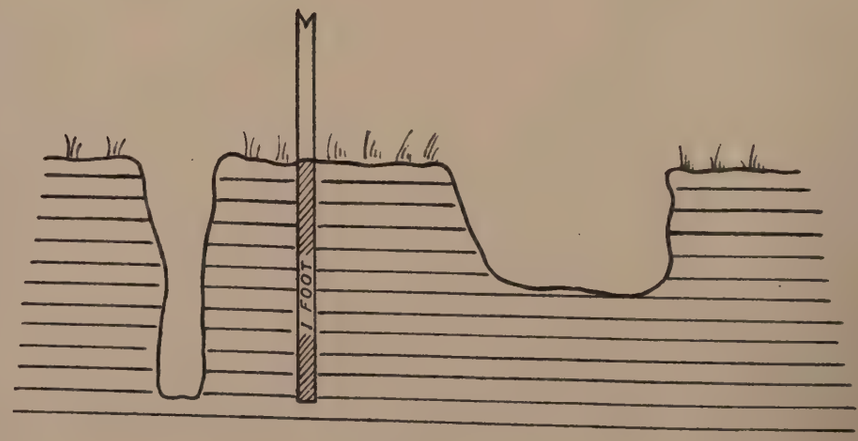


FIG. 7.

Several advantages are claimed for this tool.

First, it breaks through the pan below the depth reached by the hoe, and to this extent replaces trenching.

Second, by the use of this tool the pan is broken without bringing to the surface an excessive amount of sub-soil. Not only so, but it brings up, each time, a quantity of the sub-soil sufficiently small to be capable of incorporation in the top-soil without any injurious effect, so that by the use of the implement the top-soil is gradually deepened.

Third, by its use a much larger area can be dealt with than can be done by trenching, with the same labour, as each man can cover much more ground.

Fourth, a saving in expenditure, consequent upon the increased area which can be allotted as a task.

Fifth, less cutting of the roots of the bushes than is done by trenching.

The demonstration showed very clearly that the tool does penetrate to a greater depth than the light hoe. The tool which was used for the demonstration was 15 inches long, having been designed for use on a heavy soil, and on the light, well-cultivated soil of Tocklai sunk to the hilt at the first blow. On hard, uncultivated soil two blows were necessary to attain the full depth, but the instrument went almost down at the first blow, and everyone was agreed that an instrument, 18 inches long, could have been used with ease. Some idea of the ease with which the instrument can be wielded may be gathered from the fact that the man using the tool covered a distance of 40 feet in just under 3 minutes, which works out at 67 nulls per hour, attaining, however, a depth of only 12 inches. No cooly would, of course, maintain this rate, but it has been found that in heavy soil, with two strokes of the instrument each time, a man can easily cover 10 nulls in an hour, and has regularly performed a 40-null task.

The soil is not broken up to a uniform depth by this instrument, nor is that necessary for the purpose for which it is

designed. At each point where the instrument is driven into the soil the full depth is reached. Between those points, where of course the soil is broken by the instrument being levered upwards, the depth to which it is broken varies from the length of the prong of the instrument to about 9 inches.

One point which was noticeable, however, and which has been referred to above, was the fact that the soil was not merely broken along a line equal in width to that of the instrument, but that it was also broken up for some distance to each side, this distance increasing towards the surface, and that at the surface the soil was broken to a distance of 6 inches or more on each side of the instrument. This is shown in figure 6.

The instrument was tested, on a patch of uncultivated soil which has been grazed by cattle for years, against a really good two-chop hoe, and figure 7, which is drawn accurately to scale from a photograph, shows the difference in the depth attained. In this case the continual trampling of cattle had compacted the top-soil to such a degree that the lateral extension of the work of the tool was not so much in evidence, but the extra depth reached is clearly shown, and the ground was of course covered more rapidly.

Altogether, the demonstration clearly proved that the tool fulfils the claim made for it, *viz.*, that it penetrates sufficiently deeply to break any pan formed by continuous cultivation below the level of the deep hoe, and that by its use this pan can be broken more cheaply, and over a larger area with a given supply of labour, than can be done by trenching.

After the demonstration, a discussion of the merits and demerits of the implement took place, and all were of opinion that the tool is an efficient pan-breaker. It was pointed out, however, that there is one way in which it cannot be expected to replace trenching, and that is that its use, alone, does not allow of the burying of prunings or green-manure cuttings, and that for that purpose trenching is essential. During the discussion one planter, with long experience of a very hard soil, pointed out an exceedingly interesting possibility of an advantageous use of this tool, combining efficiency with economy, and allowing of the burial of

green matter. He pointed out that in trenching, which in most cases has to be done by contract, it is a common experience that the coolies dig the trench to the depth of the hard pan, and then go no further, stopping just at the point where digging a little deeper would be of most value. He suggested that instead of contracting for (say) an 18 or 15-inch trench and having to be satisfied with less, that a contract might be made for a 12-inch trench or less, according to the depth at which the really hard pan exists. This could be done at a very much cheaper rate, and the work would be better done, since the hard part of it would be eliminated. Men might afterwards be sent along the trenches with the pan-breaker, to break the soil below the bottom of the trench, thereby breaking the hard pans left unbroken by trenching in the ordinary way, and still allowing of the burial of prunings and other green matter. Various methods of utilising the tool would probably occur to others differently circumstanced, but the most striking part of the suggestion is that the demonstration had convinced that particular planter that the implement would be of value to him.

The implement is to be placed on the market shortly by a well-known firm of tool manufacturers, and at first only the 15-inch pattern will be made. We are informed that Messrs. Ramackers & Co., 7 Old Court House St., Calcutta, have been appointed Eastern Agents, and Mr F. Walsh, 3 Grosvenor Gardens, London, S. W. 2, Western Agent, for the sale of the implement.

E. A. A.

THE TEA GREEN-FLY.

(*Empoasca flavescens*—Fab.)

The tea green-fly has been regarded as a pest of tea, according to Mann, since 1874, and can claim to have a wider distribution, in North-east India, than any other major pest of tea with the possible exception of red spider. It is, however, a pest of which very little is known, save that it is supposed to be connected with a certain stunting of growth of the tea, and at times with the production of a special flavour in the finished product obtained from tea with such stunted growth ; and that occasionally such severe stunting occurs that serious loss in crop, without any compensating increase in flavour, is the result.

Watt and Mann, in the second edition of "Pests and Blights of the Tea Plant," published in 1903, give an account of green-fly which reflects very well the lack of knowledge on the subject at that time, and point out that it had not, up to then, been proved that stunting of the flush of the bushes was caused by green-fly.

That fact still remains unproved.

A note by Antram published in 1911 (Indian Tea Association, Scientific Department, Quarterly Journal, Part III), on observations on the life-history of the insect, is the only subsequent contribution to the literature on this subject of any value. Antram discovered the egg, and gave figures for the time taken for development of the insect whose value is, however, considerably lessened by the fact that he missed one of the larval stages.

Antram's paper contains no proof of the fact that green-fly causes stunting of the shoots.

The only experiment which has ever been recorded as having been made to decide this is recorded in "Pests and Blights of the Tea Plant," when Sir Geo. Watt and Mr. Wright of Nakachari endeavoured, but without success, to produce stunting of the growth of bushes, enclosed beneath wire gauze, by the introduction

of green-fly. Observations in the field are causing the writer to incline more and more to the belief that green-fly is not responsible for the stunting of the growth of tea. On more than one occasion, of two neighbouring sections of tea, one of which had a typical "green-fly appearance," the other of which was carrying a normal flush, the insects were to be found in greater numbers on the section carrying the normal flush. These observations have been made more or less by the way during the course of investigations on the mosquito bug pest, but the observation was of such interest, from the point of view of the results being obtained in the mosquito bug enquiry, that every opportunity has been taken, of late, to repeat it, though it has not been possible to make any actual experiments.

It speedily became obvious, however, that until something further was known of the life-history of the insect there could be little hope of satisfactorily correlating phenomena with similar phenomena relating to the mosquito bug, or with any other bug, and observations have accordingly been carried out as opportunity offered with a view to learning something more about the insect. These observations are of necessity incomplete, but they mark a small advance in our knowledge of the behaviour of the insect, and as such may be of interest.

The Egg.—With regard to the egg there is little to add to Mr. Antram's notes. All our attempts to persuade the insects to breed in captivity have, so far, failed, and we are still without definite knowledge as to the length of time spent in the egg stage. One thing is certain, that the insect may, even at the height of the season, spend longer in the egg stage than Antram alleges, for shoots plucked in June and July, containing eggs, were kept for periods as long as seven days before the young insects hatched out. The majority probably hatch out much more quickly. The frequency with which eggs hatched from shoots within a couple of days after plucking them tends to show this, but the fact is not yet proven.

The eggs are deposited, as Antram points out, in the stem and midribs of the leaves of the flush, just below the outer skin. The

egg takes the form of an elongated bean some 1/50th inch long by 1/100 inch broad. There is no visible external mark on the shoot after the egg has been deposited and before it hatches out, and so far we have been able to ascertain no method of deciding whether a shoot be infested with eggs save by keeping the shoots until a young specimen of the insect should hatch out.

Whether the egg is colourless or not it is not possible to say. The empty egg-shell is colourless and transparent, and the egg very probably remains colourless throughout development, for the insect which subsequently emerges is colourless. When the egg has hatched out the egg-site becomes visible to the naked eye as a small black speck, which would never be noticed on the tea in the ordinary way. At the centre of this black speck is often a shiny mass which is the inner skin of the egg, drawn out during the struggle of the insect during emergence. Eggs are frequently deposited in couples close together, as in the case of the tea mosquito bug, and several may be laid on one leaf or shoot.

The first Larval Stage.—The insect emerges from the egg as a small, colourless, transparent, six-legged insect, 2/100th of an inch in length, furnished with a sucking proboscis, exceedingly active, and capable of feeding on the bush immediately. The eyes appear, to the naked eye, as minute dark-brown spots, but appear pink when magnified. There is no sign of the wings in this stage. The following table shows, in days, for the various months of the year, the longest, shortest, and most usual periods spent in this stage.

Month.	Longest period.	Shortest period.	Usual period.
January	5	1	2 to 5
February	5	1	2
March	3	1	2
April	3	1	1
May	3	1	1
June	3	1	1
July	3	1	1
August	3	1	1
September	3	1	1
October	3	1	1
November	3	1	1
December	5	1	2 or 3

The Second Larval Stage.—This stage, which results from the moulting of the first stage, is larger, being 3/100th of an inch long, and is broader and flatter than the first stage. In general colour it is a translucent white, but the abdomen is beginning to take on a pale yellowish-green colour owing to the absorbed food. There is still no trace of the wings.

The number of days spent in this stage during the various months of the year is shown in the following table :—

Month.	Longest period.	Shortest period.	Usual period.
January	6	2	2
February	7	2	2
March	4	2	2
April	3	1	2
May	4	1	2
June	3	1	2
July	3	1	2
August	3	1	2
September	3	1	2
October ...	3	1	2
November	3	1	2
December	7	1	2

The Third Larval Stage.—In this stage the insect attains a size of 4/100th of an inch, and the whole insect has taken on a pale greenish-yellow colour, though it has still a translucent appearance. The beginning of the wings can now be detected as small projections at the hind corners of the 2nd and 3rd segments behind the head. The eyes are now distinctly pink, and more prominent.

The number of days spent in this stage throughout the year is shown in the following table :—

Month.	Longest period.	Shortest period.	Usual period.
January	7	2	3
February	5	2	3
March	5	1	3
April	4	1	2
May	4	1	2
June	4	1	2
July	4	1	2
August	3	1	2
September	4	1	2
October	6	1	2
November	4	1	2
December	6	1	3

The Fourth Larval Stage.—This stage shows a further development of the wings, which now project freely, and an increased resemblance to the adult green-fly. The body now shows the characteristic greenish-yellow colour, and the size of the insect has increased to 5/100th of an inch.

The following table gives the number of days spent in this stage during the various months of the year.

Month.	Longest period.	Shortest period.	Usual period.
January	6	1	3 to 5
February	5	2	3
March	5	1	2 & 3
April	5	2	2 & 3
May	4	1	2
June	4	1	2
July	3	1	2
August	4	1	2
September	4	1	2
October	5	2	2
November	4	1	2
December	10	2	4

The Fifth Larval Stage.—This stage bears a very close resemblance to the adult, save that the wings are not yet free, although the wing-pads extend to about two-thirds of the length of the abdomen. The eyes, which have been gradually changing in colour, now show the same greenish-blue colour as in the adult, and the insect has now attained a length of 7/100th of an inch.

The number of days spent in this stage during the various months of the year is as follows :—

Month.	Longest period.	Shortest period.	Usual period.
January	7	2	6 or 7
February	10	3	3 to 5
March	7	1	4
April	7	2	4
May	4	1	3
June	4	1	2 or 3
July	4	1	2
August	4	1	2
September	4	1	2
October	5	1	3 & 4
November	6	2	4
December	9	2	7

From the above records we find that the period spent in the larval stage, between emergence from the egg and the change to the adult, throughout the year, is as follows :—

Month.	Longest period.	Shortest period.	Usual period.
January	31	8	16 to 22
February	32	10	13 to 15
March	24	6	13 & 14
April	22	7	11 & 12
May	19	5	10
June	18	5	9 & 10
July	17	5	9
August	17	5	9
September	18	5	9
October	22	6	10 & 11
November	20	6	11
December	37	7	18 & 19

This table shows that at the height of the green-fly season, from June to September, the insect takes, as a rule, nine days to attain maturity after emergence from the egg. In the cold weather the insect takes twice that time to develop, but continues to remain active on the tea, to feed, and to propagate the species throughout the year. It is interesting to observe, from these figures, that the operation of plucking must exercise a considerable control on the numbers of the insects, for in an ordinary seven-day rotation the insect is at a decided disadvantage even at its quickest rate of development, being liable to be carried away in the leaf on two occasions before attaining maturity. Most of the eggs deposited after one plucking will probably have hatched out before the next plucking, in spite of the fact that some of them may take seven days to hatch, and the value of plucking as a means of control obviously lies in the collection of the insects themselves while feeding on the flush. Only the immature ones, which cannot fly, will be taken, except on rare occasions, for the activity of the insect is prodigious. Moreover, plucking to the *jhannum* is likely to be more effective as a control than plucking to a leaf, for by this means the whole of the flush is removed. Furthermore, since the tea is plucked twice, in a seven-day rotation, during the period taken by the insect to attain maturity, there is no

justification for taking immature leaf. It may result in the removal of a few more eggs and young insects at that time, but the absence of leaf above will compel the adults to deposit eggs in shoots inside the bush, when the offspring will be safe from destruction by the pluckers for one round at any rate. This will more than nullify the gain which has accrued by plucking the immature buds, quite apart from the loss of leaf occasioned thereby.

Another point shown by the table is the extreme variation which is possible in the length of time taken by the insect to attain maturity. At the height of the season, apparently, while it is usual for the insect to become mature in nine days, it may attain maturity in as short a period as five days, or it may take two-and-a-half weeks. These figures are, of course, obtained by keeping the insects in captivity, but all were kept under identical conditions save that the leaf on which they were fed did not all come from the same bush. While an insect in one cage was developing at a rate which would bring it to maturity in five days, its neighbour was developing at a rate which would delay the time taken to attain maturity to two-and-a-half weeks.

This variation is of extreme interest, and may possibly prove to be of considerable importance.

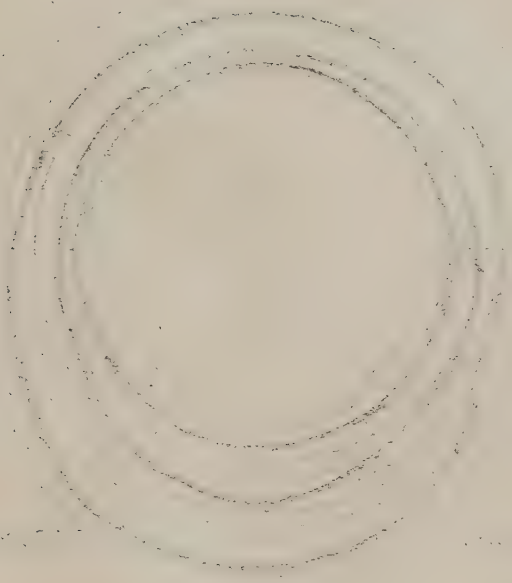
The adult forms, male and female, result from the moulting of the fifth stage larva. Their appearance is familiar to all who have been in tea for any time at all. They are winged, and capable of flight, though they never appear to fly very far. Disturbing a tea bush with a stick usually causes them to rise into the air in numbers. They are exceedingly small, the male being 1/10th of an inch long from the tip of the head to the tip of the wing, while the female is slightly longer, being 11/100th of an inch in length when measured in the same way. Both are yellowish-green in colour, and the female is provided with an ovipositor, or egg-laying apparatus, with which she thrusts the eggs into the stems. This can just be seen, with the naked eye, as a fine dark-brown needle-like process lying along the underside of the posterior half of the abdomen.

The insect feeds by sucking the sap of the plant through a jointed sucking beak with which it is provided. There is no mark left, after the leaf has been sucked, which a planter could hope to recognise with certainty in the field, and just as the position of the egg cannot be ascertained by any mark, neither can leaves which have been attacked be distinguished by any characteristic marks, although a discoloration of the internal tissues can often be seen when the shoot is dissected.

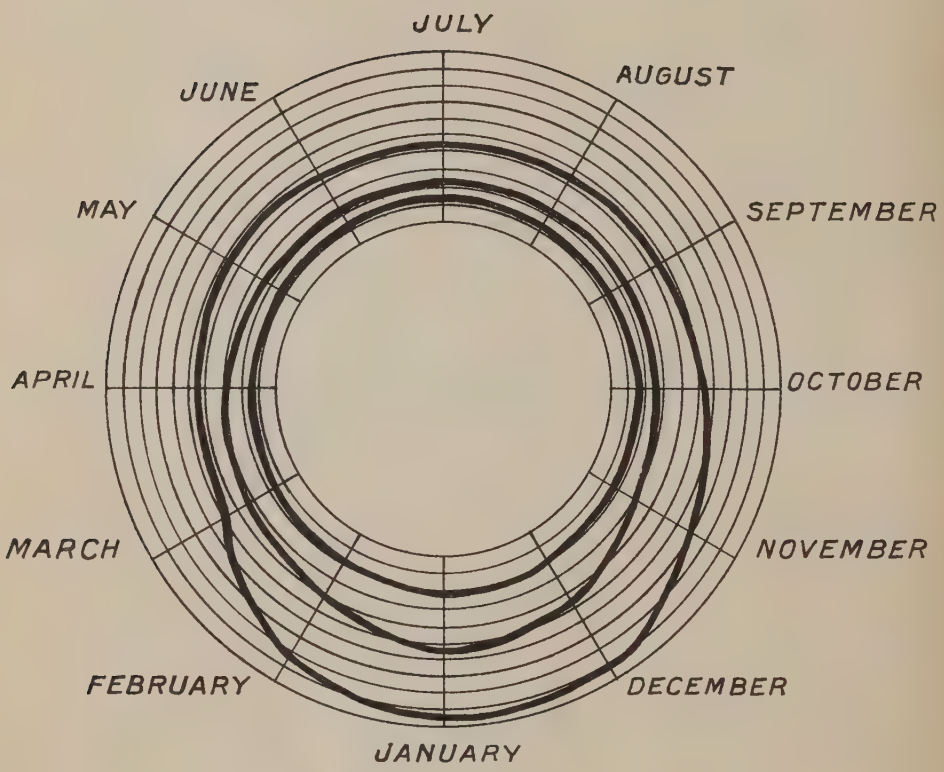
The length of time for which the adult remains alive after attaining maturity is, of course, a matter of importance so far as control is concerned, and Antram *(loc. cit.)* published figures to show that the adults may live for two months at the height of the season, and during the cold weather for six weeks. His conclusions were based on the results of the observation of some 300 cases. In our observations, which comprise over 800 cases, we have found, on the contrary, that, under laboratory conditions, the length of time for which the adults remain alive is much longer during the cold weather than during the height of the season. During this latter period the insects commonly lived for a fortnight and then died, although many were kept alive for longer periods. During the cold weather, however, they were kept alive without any difficulty for a month, while many lived much longer, two months being common, and one specimen, which attained maturity in November, living for 102 days before it eventually died in February. Several of the insects which attained maturity in November lived for more than two full months, and died in January.

The longest period for which any specimen which attained maturity during the various months of the year remained alive is as follows :—

January	...	...	50 days.
February	...	...	28 „
March	...	...	28 „
April	...	...	23 „
May	...	...	28 „
June	...	...	24 „
July	...	...	18 „



DEVELOPMENT OF GREENFLY
FROM EGG TO ADULT



INNER LINE QUICKEST RATE OF DEVELOPMENT.
OUTER " SLOWEST " " "
CENTRE " USUAL " " "
THE CONCENTRIC CIRCLES INDICATE FOUR DAY INTERVALS.

IMPERIAL ART COTTAGE. 41, RATU SARKAR LANE, CALCUTTA.

August ...	...	29 days.
September	...	14 „
October ...	...	39 „
November...	...	102 „
December ...	...	66 „

It is difficult to reconcile this experience with that of Antram, and there is no doubt that the insect which lives for a longer time during the cold weather than during the rains has a better chance of surviving than one whose span of life decreases at that time, when conditions become adverse. There is, moreover, no doubt that green-fly does survive the cold weather, and a theory of hibernation has been postulated at times, but if the insect can remain alive and active for 102 days no such postulation is necessary, and it becomes obvious that in the case of this insect, as in that of the mosquito bug, complete eradication of the insect by pruning, etc., in the cold weather, can never be anticipated.

Attached to this article is a diagram, showing the usual, longest, and shortest periods taken by the insect to attain maturity, after emergence from the egg, throughout the year. Each of the concentric circles represents a period of four days. The inner curve represents the quickest rate of development, the outer curve represents the slowest rate of development, and the centre curve the usual rate of development.

The length of time spent in the egg stage, and various other items, still remain to be discovered, and, most important fact of all, *it still remains to be proved that green-fly is responsible for the stunting of the bushes for which it has been given the blame for so many years.*

E. A. A.

TERMITES.

A leaflet* has recently been published by the Department of Agriculture in Ceylon in which Dr. J. C. Hutson, the Government Entomologist, describes the various species which attack tea in that colony. Dr. Hutson divides the termites which attack tea in Ceylon into two classes :—

> "(*a*) Termites which form their colonies inside a living "tea bush and bore into the heartwood. These are "primary pests, and include the well-known *Calotermes* "*militaris*.
>
> "(*b*) Termites which have their nests outside a tea bush, "usually underground, and which generally attack the "dead or dying bark and wood of various plants, "including tea, rubber, dadap, grevillea, and jungle "stumps. These include the mound-building termites, "and can be regarded mainly as secondary pests and "scavengers."

and then goes on to say :

"The prevailing anxiety about the tea termites seems to be "due mainly to the state of uncertainty as to the actual species "of termite concerned in any particular case, and where there is "any doubt in the mind of the planter, the damage is usually "attributed to *Calotermes militaris*, when, in most cases, the "injury is usually the result of an attack of a fungus disease or "of insect injury followed by an invasion of the scavenging "termites."

Termites of both classes affect tea in North-east India, but the depredations of those of class (*a*) are usually confined to seed baris, so much so that they can hardly be ranked as pests of plucking tea, and the notes on termites in the Luskerpore Valley

* "Notes on Termites Attacking Tea in Ceylon," Ceylon Dept. of Agric., Leaflet No. 24, 1923.

published by the writer some years ago* dealt exclusively with species in class (*b*).

Dr. Hutson's remarks on the depredations of this class of termite show that the Ceylon species work in a manner very similar to that in which the North-east Indian species work, and that the presence of dead or dying bark or wood is necessary before they can obtain a foothold in the bushes, thus :—

> "In the opinion of the writer the prevalence of branch "canker on many tea estates has been one of the "contributing causes of the marked increase of these "termites on tea bushes within recent years. The "branch canker fungus usually occurs along the "upper surface on lateral branches, invading and "killing the cambium layer inside and causing the "bark to crack. The disease may also extend down "to the main stem, and in extreme cases may "girdle and kill the bush. The scavenging termites "come along and gradually clear away the dead bark "and crumbly wood inside, usually working "under a screen of earth. Eventually, many of the "horizontal branches are left with shallow, irregular "cavities along their upper surface, and the main stem "may also be partially excavated by the termites, "which have merely cleaned out the portions of the "bush killed by the canker. These injuries are "frequently attributed by the planter to the work of "*Calotermes*, especially when there is a fairly deep "cavity in the main stem, but in the case of a great "majority of cases this particular type of injury is "due to the branch canker followed by these smaller "termites, such as *obscuriceps* and *redemanni*.
>
> "Incidentally, these termites may also be gradually clearing "any old stumps and logs left among the tea, and the abundant "supply of such food on some estates has encouraged these insects "to extend and populate their underground colonies.

* Indian Tea Association, Scientific Department Quarterly Journal, 1916, pp. 54-72.

"It has been claimed that in some cases these smaller termites "may help to prevent wounds from healing over, and that they "sometimes eat away living bark and girdle young tea bushes, "but there is no definite evidence that they ever attack healthy "living plant tissues. It is true that they usually follow the "advance of a disease so closely that it is difficult to say that they "do not actually get ahead of it sometimes. In the great majority "of cases, however, it is quite evident that they are merely "scavengers of dead and diseased bark and wood."

Dr. Hutson recommends that control measures should follow three main lines.

"(1) A direct attack should be made on the termites by "eradicating their nests.

"(2) Their food supply on the tea bush should be reduced "by controlling branch canker and other diseases, "shot-hole borer, red borer, *Calotermes*, and other "insects which injure the frames of the bushes.

"(3) Their other sources of food supply should be cut "down as far as possible by removing and burning "all old stumps and logs which are sometimes found "among the tea."

The notes on termites of class (*a*) may be of interest to those who have seed baris which are infested by termites, and they are therefore quoted *in extenso*.

"(*a*) At the present time there are only three species of "termites which are known to bore into the heartwood of healthy "tea bushes. These are (1) *Calotermes militaris*, (2) *Calotermes* "*dilatatus*, and (3) *Calotermes greeni* :—

"(1) *Calotermes militaris*.—This termite was investigated "some fifteen years ago by Mr. E. E. Green (then Government "Entomologist), and the results of his observations were published "in the 'Tropical Agriculturist' for March, 1907. Green "found that this termite works entirely in the heartwood of the "bush, and that the branches, the main stem, and even the roots

"may be completely hollowed out, leaving merely a hollow shell. "He observed that in spite of this extensive damage the bushes "continued to flush well and showed no external sign of injury, "the reason for this being that only the heartwood is devoured, "while the sap wood remains intact and carries on the functions "of the plant. The devoured tissues," he continues, "are replaced "by earthy matter into which adventitious roots are thrown "out apparently from the inner walls and evidently obtain much "nourishment from the earthy matter. Green further observed in "digging out infested tea bushes that there were no signs of any "extension of the termite galleries into the surrounding soil, nor "were any of the insects found in the excavated soil. Green "found nothing resembling a specialized queen, such as are found "in some of the mound-building species, nor any indication of "special brood cells or honey-combed nest. The adult termites, "or kings and queens, are wingless,* and the eggs are laid inside "the bush. Green concludes that each colony is self-contained, "and that the removal and destruction of the infested tea bush "should destroy the complete colony. The presence of the pest "can seldom be recognized until the bush has been pruned, when "sections of the galleries are exposed. Green was of opinion that "in recently attacked bushes only collar pruning can disclose "the infection, as the insects apparently effect their entrance "through the roots, working up first into the stem and later into "branches."

"Neither the late Mr. Rutherford (Mr. Green's successor) nor "the present writer have been able to confirm this last obser- "vation. It is possible that in some cases the *militaris* "termites may enter the bush below ground, but it seems probable "that another method of entry is through some weak spot above "ground, such as a decayed knot-hole or old borings of the shot- "hole borer, or else of the red borer, as in the case of *C. dila-* "*tatus*."

"A typical colony of *Calotermes* may be developed some- "what as follows:—A royal couple, resembling each other in

"* Winged adults were found in 1909"

"size and external appearance, on emerging from an infested "tea bush, may find their way to a neighbouring uninfested "bush into which they gain entry either below ground or "through some weak spot above ground, as mentioned previously. "It is possible that the royal pair may be attended by workers "from the parent colony, but the queen lays her eggs probably, "in a small cavity in the tea bush. These eggs develop into "workers, and probably a few soldiers, which are at first looked "after by the queen and by any attendant workers. All the work "connected with the building up of the colony is done by the "workers, which are blind and work entirely under cover inside "the tea bush. Eventually, a complete colony, consisting of "different castes, is developed within a bush. There are the workers "of various ages, the younger ones being whitish with small rounded "whitish heads, while the other ones are mottled white and brown-"ish with pale brown heads and stout, blackish, toothed mandibles "or jaws. The workers usually form the majority of the inhabit-"ants of a *Calotermes* colony, and at first are sexless, but are "probably developed into fertile males and females, either winged "or wingless, as required by the needs of the colony. The soldiers "are conspicuous by reason of their large, elongate brown heads "armed with rather long, curved black jaws. They have pale spots "on the head representing eyes, but it is not known how far these "are functional. The soldiers are few in number as compared "with the workers, and it is their duty to protect the colony from "invaders."

"*Calotermes militaris* is mainly an up-country species, being "prevalent mostly in the southern part of the Central Province, "but it is sometimes found at lower elevations. This termite is "intermediate in size between the smaller *dilatatus* and the larger "*greeni*. It is a fairly serious pest on some up-country estates."

"(2) *Calotermes dilatatus*.—This is the smallest of these "three species of termites. It seems to be mainly a mid-to low-"country species. Rutherford was of opinion that this termite "enters a bush through some old knot-hole or a wound, or through "a red borer or shot-hole borer gallery, and gradually works

"downwards, sometimes into the roots. The writer has observed "this habit in the case of this species in tea seed-bearers, a series "of attacked bushes showing progressive stages of injury from "top to bottom and even down into the roots. In the case of "*dilatatus* the galleries are distributed throughout the stem, and "neither Rutherford nor the writer has observed any large cavities "formed by *dilatatus*, such as are found in the case of bushes "infested with *militaris*. A complete colony apparently exists "in each infested bush, and this species is known to have winged "adults."

"(3) *Calotermes greeni* appears to have a wide range of "distribution and feeding habits, as it has been recorded from Jaffna "('boring into trees'), Peradeniya ('in dead branch of tree'), "Avissawella and Yatiyantota ('from stem of living tea bush'), "and Ambalangoda ('from stem of living Cashew-nut tree'). In the "single instance seen by the writer of a tea bush infested by this "species, the damage was somewhat similar to that done by "*dilatatus*, in that the stem was fairly well riddled by galleries "without any large cavity being made. *C. greeni* is the largest of "these three species, and has winged adults.

"To summarise, it may be said that, so far as we know at "present, the *Calotermes* species all have their nests inside living "tea bushes, *militaris* being more prevalent in up-country tea, "while *dilatatus* and *greeni* occur at lower elevations. In case of "injury by *militaris*, it is usually the lower parts of the bush, "from the collar down to the roots, which suffer most; but in all "the *militaris* cases noted by Rutherford, and in those observed "by the writer, the injury was so far advanced that it was impossi-"ble to say where the termites had originally entered. Green was "of opinion that these termites apparently enter a bush through "the roots and work upwards. It is not improbable that *militaris* "may sometimes gain entry through an injured branch from which "the termites may spread in all directions throughout the bush.

"Judging from the records of *dilatatus* injury left by Ruther-"ford and from the present writer's experience of this species "in tea seed-bearers and ordinary tea bushes, it seems not unlikely

"that *dilatatus* may enter a bush above ground and may tunnel "into the lateral branches and later work downwards, although it "may possibly sometimes attack a bush from below ground level. "Neither *dilatatus* nor *greeni* appear to excavate large cavities in "the main stem, but have a system of galleries running through the "heartwood.

"Of the above species of *Calotermes* it seems probable that "*militaris* is the most formidable as a pest of tea, since it may "escape detection at pruning time and continue its excavations for "many years until the bush is reduced to a mere shell. Even in "cases where it may enter a bush above the collar, being mainly "an up-country species, it has a longer time to carry on undisturb-"ed between prunings. On the other hand, *dilatatus* and *greeni*, "probably working for the most part above ground level, would "tend to be periodically controlled by pruning, especially by the "more frequent prunings at lower elevations.

"None of these three species has been a really serious pest "within recent years, only small patches of tea or individual bushes "being occasionally attacked.* Much of the damage reported as "due to *Calotermes* on further investigation usually turns out to be "the work of the scavenging termites, following an attack of "branch canker or other injury to the bushes."

Control of the *Calotermes* species.

"Since these termites have their colonies in individual tea "bushes, and are not known to nest in the ground or have any "main termitarium outside the bushes, it follows that the most "effective way of reducing their numbers is by treating each "infested bush individually on its merits. All completely riddled "bushes should be eradicated and burnt immediately, so as to "destroy any infesting termites. In cases where the injury is "detected in time, it should be sufficient to clear out any cavity "thoroughly and paint the inside with a liquid wood preservative, "such as a creosote solution, and then fill in the cavity with "mortar or cement to prevent water collecting and causing decay.

"* Recent reports indicate that *Calotermes* species are on the increase in some districts."

" Where there is no cavity, but only small galleries, the solution can " be applied thoroughly to the cut surface and allowed to penetrate " into the galleries. This should effectually drive out or kill any " termites which are still inside, and protect the bush from re- " infestation for some time. The presence of the scavenging " termites may sometimes complicate matters, and in such cases the " use of ordinary tar should be avoided, as this seems to afford no " protection against the scavengers."

E. A. A.

SOME OBSERVATIONS ON MICRO-ORGANISMS ASSOCIATED WITH TEA FERMENTATION

BY

A. C. TUNSTALL, B.SC.

At the suggestion of the Chief Scientific Officer the writer commenced an investigation of the micro-organisms found in fermenting tea leaf. These investigations have been continued for some time at intervals as the work on tea diseases permitted.

Considerable research on this subject has been carried out in Java and the results of the Java scientists have been published from time to time in the "Mededeelingen van het Proefstation voor Thee." They discovered that there were a number of micro-organisms always present in fermenting tea. They isolated some of these organisms and came to the conclusion that moulds and bacteria were harmful while the yeasts, while not being harmful, did no apparent good.

As the conditions in Java differ considerably from those of the tea districts of North-East India it was decided to disregard the conclusions arrived at in Java and to carry on the investigation with an open mind.

A start was made by isolating the various organisms present in fermenting leaf and growing them in pure culture. A number of bacteria and various yeasts were found. Few moulds were present.

In order to test the effect of individual organisms an attempt was made to sterilise tea leaf. It was obviously undesirable to sterilise the leaf by heat as by so doing the chemical composition would be changed. Various chemical substances were experimented with including Chloroform, Chlorogen, Formalin, Hydrogen peroxide and Corrosive sublimate, but in every case where complete sterilisation was obtained the nature of the leaf was so altered as to be useless for our purposes.

It was therefore decided to carry out the inoculation experiments without sterilisation, using such overwhelming numbers of the organisms concerned that the effect of the organisms already present would be entirely masked. The results of the preliminary experiments showed that the bacteria isolated produced undesirable taints while the yeasts generally produced a desirable aroma, and in some cases a difference in taste. It was further noticed that the aroma produced by the various yeasts differed considerably, but none were undesirable. In the course of the culture experiments it was noticed that some tea medium had been accidentally infected with black mould (*Aspergillus niger*). Reference to scientific literature on the subject showed that this mould was known to produce an enzyme when grown on ordinary oak-tannin solutions. Further experiment showed that the mould produced an enzyme when growing on tea-tannin, and a quantity of this enzyme was isolated.

Some experiments were then carried out to ascertain the effect of the mould-enzyme on tea leaf in which the enzymes naturally present had been disorganised by heat. From our observations it would appear that the mould-enzyme brought about similar changes in the leaf as that produced by withering, *i.e.*, the rawness was changed to pungency and the green colour of the infusion to a golden-yellow. No brown colour characteristic of fermented leaf was noticed even after 21 hours. The enzymes produced in the leaf during withering and those produced by various yeasts were also isolated. Experiments with these seemed to indicate that the aroma of fermenting tea was due to the action of yeast and that the aroma was not observed unless the leaf had been withered or the tea-enzyme or the mould-enzyme were added. At this stage further experiments on these lines were postponed as time could not be spared to continue them.

Experiments were made to ascertain the micro-organisms present on fresh leaf, withered leaf, fermenting leaf, at the beginning and end of fermentation, and from the various machines, floors, etc., with which leaf comes into contact during manufacture. It was found that yeasts predominated on the leaf, and that there

was a steady increase of the number of yeast cells present as the manufacture proceeded until the maximum was reached when fermentation was completed. The rollers, sifters, fermenting-floors, etc., contrary to expectation, contained very few yeasts but often many bacteria.

Some of the bacteria isolated from fermenting rooms were found to give characteristic taints to the tea. One was responsible for a taint resembling that produced by over-firing.

Tea-juice expressed during the rolling was found to contain a collection of organisms representative of those found on the leaf. Samples of tea-juice were obtained from many gardens and pure cultures prepared of the yeasts present therein. When sufficient quantities of pure yeasts were available tests were made by inoculating the leaf at various factories. Samples of the dried tea manufactured with and without the addition of pure yeasts were sent to leading tea tasters for report. It was found necessary to inoculate each roll of leaf as the yeasts did not propagate themselves on the fermenting-floors. Inoculation of the fermenting-floors was therefore useless.

At first it was noticed that the yeast-treated tea was frequently less brisk than the corresponding untreated tea. It was then found that the yeast-treated tea often fermented more rapidly. It was also noticed that the temperature of this tea rose more rapidly during fermentation than the other tea. Careful temperature observations were made at short intervals and it was found that the rise in temperature in both followed a characteristic curve during fermentation. It was also found that by spreading the leaf more thinly on the fermenting-floors the temperature of the yeasted tea could be kept down. When this was done the time of fermentation of the yeasted and unyeasted tea was approximately the same. It was also noticed that in many cases by spreading unyeasted leaf thicker and thus raising the temperature the time of fermentation was shortened. If, however, the leaf was pressed down so as to exclude air the temperature did not rise and the time of fermentation was lengthened considerably. When air was all excluded by placing the leaf in an atmosphere of carbon dioxide the colour of

the leaf did not change even after 24 hours. The aroma of the yeasted samples developed satisfactorily even under these conditions. In this connection experiments were made to ascertain whether the yeast destroyed the tannin. Leaf, treated with yeast and without yeast, was packed tightly into a number of glass tubes immediately after rolling and sealed up with wax. The tubes were kept at a constant temperature. Tannin estimations were made at intervals by the Chemical Department. No loss in tannin was noted in either the yeasted or unyeasted leaf in 24 hours. Some of the leaf from the tubes was then exposed to air and the loss in tannin estimated. There was a steady loss in tannin in both cases comparable with that normally lost during fermentation, but the yeasted tea fermented more rapidly.

A sterile solution containing pure tannin isolated from tea leaf by the Chemical Department was inoculated with yeast. No loss in tannin was observed even after a long period.

It would seem therefore that the yeast does not act directly on the tannin. The aroma produced by fermenting leaf varies from garden to garden and it is found possible by the use of yeast obtained from a particular factory to reproduce the aroma characteristic of the fermenting leaf in that factory in another factory, on a different class of leaf, in another district.

In many cases at the commencement of the experiments the aroma obtained in the fermenting room was not retained after drying. By improvements in the methods of cultivating the yeast it was found possible to obtain better results and the aroma was retained by the tea after drying.

Not only has it been found possible to change the aroma on a tea, but also to change the flavour.

At first it was suggested that the improvement in the treated tea would go off on keeping, but subsequent experiments have proved that the results are permanent.

Every planter knows that the quality of the tea varies with the time of the year. Observations of the micro-organisms present on the leaf at different times of the year show that the

quantity of yeast on the fresh leaf is at its maximum when the best quality teas are being made. It has also been discovered that the yeast present when the best quality is being obtained is more active than that found at other times of the year. Yeast has been isolated from leaf on a number of gardens when the best quality was being made. The yeast cultures were stored for the time being and when the quality was no longer apparent the leaf was artificially inoculated with these yeasts with beneficial results. So far it has not been found possible to improve the flavour of the tea when first class tea is being made. It was found that yeast cells were naturally present in large numbers at that time and the addition of pure cultures of yeast had no apparent effect.

It is interesting to note that in growing the cultures of yeast from a number of gardens the individual selections showed a marked preference for culture medium prepared from tea leaf or tea-juice obtained from the garden whence they came. In the case of one yeast this was noticed after the yeast had been grown on tea medium obtained from other gardens for over a year.

It must not be assumed that by the use of pure yeasts it is possible to make Darjeeling tea in districts less favourably situated. Flavour and aroma alone are not the criterion of price. The yeast undoubtedly influences flavour and aroma, but it cannot put pungency and strength into leaf which does not possess it already, neither can it alter the appearance of a tea. So far it has not been possible to obtain anything approaching the amount of flavour present in a first class Darjeeling or Upper Assam tea on teas of other districts.

The addition of pure cultures of yeast does not add anything to the leaf. The yeast is only able to act on the substances present in the leaf. It is merely an agent which is able under proper management to make the most of the substances on which it works.

Our experiments have shown that in many cases the use of pure cultures of yeast has improved the tea, but much more work is required to render it possible to get the results in all cases.

The writer has avoided reference to the technical details of the experiments as they are beyond the scope of this article. Over 3,000 pure cultures have been made in the course of the investigation and the work is by no means complete. A scientific study of the properties of the various yeasts so far isolated is being continued systematically and considerable improvement on the results so far obtained may be confidently expected.

In conclusion I should like to take this opportunity of thanking the managers and the tea tasters who are so kindly co-operating in this work.

Summary.

1. Certain micro-organisms influence the flavour and aroma during fermentation.

2. Under certain circumstances it is possible to improve the aroma and flavour of tea by the use of pure yeasts in fermentation.

3. The yeasts are present on the fresh leaf and increase during withering and fermentation.

4. In the cases investigated, improved flavour and aroma is associated with increased numbers of the yeast cells naturally present on the leaf.

5. The organisms found on fermenting floors, rollers, etc., are usually undesirable.

ROOT DISEASE IN NORTH LAKHIMPUR.

As another article appears in this journal dealing with the soils of the North Lakhimpur district it is opportune to draw attention to the prevalence of root disease in that district. Fungus diseases are not especially prevalent there with one notable exception—Brown root disease. This disease is always more prevalent on sandy soils which have recently been opened out from virgin forest. The older forests of Assam wherever they are growing on sandy soil are bádly infected. In opening out such forest it is of the utmost importance to remove and burn as much of the dead timber as possible.

No fructification of the fungus has ever been found on tea nor has it been produced from cultures. In consequence, it was impossible to identify it with certainty. It was thought to be *Hymenochaete noxia*, but it is more probably identical with a species of *Fomes* commonly found in the jungle. The fruits of this fungus have been found on decaying logs in contact with tea bushes which have died of Brown root-rot and the appearance of the fungus in the decaying jungle wood was identical. However, the scientific name does not matter much to the planter, but the fact that the fungus produces spores in the jungle, though not on tea, is of great importance. It is unnecessary to describe this disease, as every planter in North Lakhimpur knows it only too well. There is no known method by which a tea bush already attacked by this disease can be saved and no method of soil sterilisation has been found wholly satisfactory. The only satisfactory way of dealing with outbreaks of Brown root-rot therefore is to remove all dead wood and burn it wherever the disease is found. Any jungle tree stumps showing signs of fungus disease of any kind should be dug out and burned as soon as possible. Stacks of decaying logs should not be allowed to slowly decay away in the neighbourhood of the tea. They should be burned without delay. No wooden bridges or fence posts should be

placed in the tea unless the wood is properly treated with Atlas compound or other satisfactory preservative. Care should also be taken to prevent coolies dropping fire wood along the paths in the tea. Another point of importance is the burial of prunings on gardens subject to this disease. No heavy prunings should be buried, and where trenches are filled in with prunings, etc., the trenches should not be continuous, so that the fungus has less chance of spreading along the trenches for long distances.

The disease usually attacks well-grown bushes, but there are instances of young plants also being attacked. In one case thousands of plants died in one year on a young clearance. The cost of clearing all the dead wood from a new clearance is heavy, but it is amply repaid. Tree jacks are found very useful for removing the smaller tree roots. If the smaller roots and logs are piled round the big stumps and burned many of the latter will be considerably reduced.

A. C. T.

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